Project of Estimation and Classification

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Goal

This project aims to perform self-localization of a robot, provided a map and the information of its sensors. The information of the robot motion is not know. The map is composed of a grid that may contain obstacles. Both the grid dimensions, the position of the obstacles, and the sensor data are given.

On the robot localization, motion, and sensor operation should be modelled using a Hidden Markov Model (HMM).

Environment

The robot is represented as a point in a 2D grid of $N \times N$ points ($N \in \{20, 30\}$), called the *environment*. The environment may contain obstacles (e.g., one or more "L" shapes), and the robot cannot occupy obstacle positions or move towards them. Several environments can be considered and they are assumed to be known in advance.

Robot Motion

The robot motion is not known *a priori*. It should be modeled as a random walk in discrete time. The position of the robot at instant t depends on its position at instant $t-1$ but does not depend on previous positions (Markov property). At each time instant, the robot may stay in its current location or move to any of its 8-neighbour positions, provided that they are free of obstacles. This movement should follow a uniform probability distribution that accounts for the number of grid neighbours free of obstacles.

Sensors

The robot detects obstacles in four compass directions (N, E, S, W) using binary sensors with a range of one grid step. The sensors inform the robot whether there are obstacles in each of the four directions up to that range. The sensors have an error probability of $p_e \in [0, 1]$. Perform perform simulations and localization runs with $p_e = 0$ (ideal sensor), $p_e = 0.05$ (normal sensor), and $p_e = 0.4$ (faulty sensor).

Self-localization

The self-localization module should estimate the probability distribution of the robot position in the grid at time t, taking into account the map and the observations up to this instant.

Simulation

To gather ground truth data for evaluation, a simulation of robot motion and sensor readings should be performed. The simulation requires a initialization of the robot localization (this will not be available during self-localization) and iterates the HMM with stochastic sampling, using the robot motion and sensor characteristics. Optionally, the most probable trajectory can also be computed and displayed as a line in the grid.

Graphical Interface

The students should provide a graphical interface showing the grid, the obstacles, and the moving robot. The interface should allow free-run mode or stopping after each instant of time. The graphical interface should show the robot position and the probability distribution of the robot position as an image. The interface should support free-run mode or stopping at each instant of time.

Code Template

A code template in `python` with a working simulation and graphical interface is made available in a `github` repository[1]. The code includes placeholders to define the HMM and the self-localization functions. Student's may use the code freely, in parts or completely, extending it with the required addition to fulfill the objective os the project. The repository includes a `README` file with instructions. Any help can be requested via email.

Report

A short report (2 pages) should be written. It must describe how the HMM was represented and how the position distribution was computed. The report should also contain images of the interface to illustrate system performance.

Warning

Please be aware of the difference between a simulation and an inference process. Somethings known in a simulation (the initial robot position, the robot movements) are not available for inference. Make sure there is no "information leak" from the simulation to the self-localization module.

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[1] https://github.com/alcedok/IST-EC-course-project